RELATIVE HUMIDITY AND SHORT-PERIOD FLUCTUATIONS IN THE MOISTURE CONTENT OF CERTAIN FOREST FUELS

By A. GAEL SIMPSON

Forest protectionists in the Douglas fir region of the Pacific Northwest are probably more interested in relative humidity than in any other one weather element, both because of its effect on fire and on forest fire fuels. Unquestionably it is a powerful factor in fire behavior.

One important function of humidity is to cause changes in the moisture content of the forest fuels. In general, low relative humidity tends to rob the fuels of moisture, while high humidity contributes moisture to them.

The most rapid moisture changes may be expected to occur in light, porous materials having a high ratio of surface-to-volume such as weeds, mosses, leaves, twigs, and a very thin layer on the outside of the larger materials such as branches and logs. Though the light débris usually represents but a small portion of the total volume of fuel on forested or cut-over areas, it is the kindling and fire carrier to the heavier stuff. Flash materials occupy a place of about the same importance in forest fires as does paper and kindling in building a fire in your cook stove or furnace. The dryness of the kindling, whether it be in the forest or in the kitchen range, has much to do with whether or not the fire will start.

The moisture condition of the forest kindlings can, and often does, change astonishingly in a very short space of time. They may be saturated and literally dripping with dew in the morning, yet dry out to a highly inflammable condition before the day is over. Hence, the fire fighter watches the humidity with anxious eye and notes its effect on the flash fuels, for when they have dried to inflammability danger is at hand. Conversely, after they have absorbed moisture in excess of the critical value, the chances of fires starting or spreading are enormously reduced.

It has been said that "some materials burn; others are burned." The thought might be revised to read thus: "Sometimes a material burns; at other times it is burned."

On a going fire, the beginning of the fire day or fire period dates from the time such light materials as fern and outside of snags begin to burn and carry fire. Enough heat may be generated to consume some of the more sluggish fuels that are still too damp to ignite without this additional drying. The one burns, the other is burned. As the day advances, the humidity falls and the fuels continue to give off moisture to the atmosphere so that additional materials are shifted from the "are burned" to the "burn" class until a roaring climax is reached when all of the fuels are at the peak of the "burn" condition. Then, when the humidity rises, the more moisture sensitive fuels are first to absorb water vapor and enter the "are burned" class and are followed in order by the denser fuels.

Experience points to a close affiliation between fuel moisture and atmospheric humidity and laboratory experiments bear this out. As a basis for a study of this apparent relationship, hourly measurements were made of the moisture content of 21 forest fuels, together with concurrent hydrometric data at the Wind River laboratory of the Pacific Northwest Forest Experiment Station. Samples of the following materials were used: Braken fern, fireweed, hawkweed, pearly everlasting, creeping blackberry, Oregon grape, salal leaves and twigs, fire-killed vine, maple leaves, gray moss from Douglas fir trees, Douglas fir, western hemlock, western white pine, lowland white fir duffs, decayed Douglas fir wood and decayed hemlock wood, decayed sap of Douglas fir snags, outside one-eighth inch of Douglas fir snags, Douglas fir needles and twigs from slash, Douglas fir twigs, bark from Douglas fir snags, and bark from hemlock snags.

During the period covered by the measurements, the fuel samples were suspended 4½ feet above the ground level in wire-screen baskets of 1 cubic foot capacity. In all something over 2,000 measurements were made. Graphing 72 consecutive hours of these data showed that the daily fuel moisture curves had a form similar to the daily relative humidity curve. However, the peaks and valleys in the fuel moisture curves did not exactly coincide with those in the humidity trace. Instead, the fuel moisture lagged appreciably behind the relative humidity. The amount of this lag, or inertia, seemed to vary with the kind and condition of the fuel.

Both the humidity and moisture-content curves normally show a daily periodicity in that there is a daily rise and fall in atmospheric and fuel moisture. Usually they attain maximum values during the night and fall to a minimum during the day.

The periodic nature of the data suggested one of the two methods of analysis used—a very convenient method but one which, so far as I know, has not heretofore been applied to studies of this sort, though frequently applied to other types of data.

To illustrate the method, I have used moisture-content measurements of Douglas fir duff together with appropriate humidity data. The solid line curves show averaged values for each hour of the 24, based on 72 consecutive hourly measurements.

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That may seem like a short time, but remember we are making comparisons of simultaneous observations rather than seeking normals. Measures of the sufficiency of the data will be discussed later. Appropriate sine curves have been passed through the data as shown by the broken lines and their respective phase angles. computed. The difference in phase between the two curves represents the best value for the lag of the duff moisture curve behind the relative humidity curve. In this case an hour and a half.

Similarly the lags of a number of other fuels were computed. However, I will give only a few representative ones.

It was found that fern, representing the weed group, lags one hour; the outside one-eighth inch of Douglas fir snags, representing that part of the snag first likely to ignite, lags about an hour and a quarter; Douglas fir duff, representing the duff fuels, lags an hour and a half; and wood, decayed to the disintegrating stage, lags a little more than two and one-quarter hours.

A good relationship between relative humidity and duff moisture has been indicated, and by inference, a relationship may be expected to exist between humidity and other fuels more or less similar in character. Two questions present themselves, namely, how good is this apparent relationship, and, can fuel moisture be estimated from appropriate humidity data.

The relationship appears to be reasonably close. For instance, a correlation of the average relative humidity during the 60-minute period immediately preceding each measurement of the moisture content of braken fern gave a positive correlation coefficient of 0.97, which is not too far removed from 1, or perfect correlation.

Douglas fir duff moisture when correlated with the average relative humidity for 60-minute periods ending one hour before the moisture measurements also gave a positive correlation of 0.97. (The sine curve analysis showed duff to have a lag of about one and one-half hours.) Correlation of the moisture in decayed wood with humidity data likewise yielded a positive correlation of 0.97. Of the 21 fuels studied, western white pine duff gave the best correlation, 0.98, and lowland white fir duff gave the poorest, 0.89.

As indicative of the sufficiency of the data for correlation purposes, the standard deviations of the correlation coefficients were found to be of the order of ± 0.01.

Estimates of current fuel moisture conditions based on atmospheric relative humidity show standard errors of estimate ranging from ± 2.3 per cent moisture for pearly everlasting down to but ± 0.3 per cent moisture for Douglas fir twigs. For example the standard error of the estimates of braken fern moisture was calculated to be ± 1.6 per cent moisture. Attaching the usual significance to the standard error of estimate it is assumed that, with a normal distribution, about two-thirds of the errors resulting from the use of the estimating equation will not exceed ± 1.6 per cent. The greatest errors were found to occur when the estimates were based on high humidity values such as often occur at night.

No attempt has been made here to evaluate the seasonal trend of fuel moisture nor the eccentric fluctuations due to precipitation, for that requires a somewhat different treatment. Nevertheless, the study does furnish a method of approximating fuel moisture during the mid-season dry weather.

It is hoped that the results of the study may be of assistance to the fire fighter in estimating the length of the fire day, its severity, and the hours of fire danger on areas where the types of fuel are known.

On going fires it should aid in anticipating the degree of inflammability of the various fuels and also aid in the proper disposition of the fire suppression forces.

Also a knowledge of the degree and rapidity with which the various kinds of forest fuels respond to relative humidity is essential to good slash burning technique. Estimates of fuel moisture should help the slash burner to calculate the proper time at which to fire his slash in order to get the best burn with a minimum danger of the fire spreading beyond the slash area.

NOTES, ABSTRACTS, AND REVIEWS

The Quarterly Journal of the Royal Meteorological Society.—Though a good many copies of the excellent Quarterly Journal of the Royal Meteorological Society are received by meteorologists in the United States, there are interested readers who may not have seen this Journal recently. A brief review of the contributions in the January, 1930, issue shows the importance of this outstanding meteorological quarterly.

M. G. Bennett discusses "The physical conditions controlling visibility through the atmosphere." First, he worked up the theory with the aid of laboratory experiments, and then tested his conclusions in the field. The relative effects of screening, diffusion, and glare upon visibility are expressed in an empirical formula. Mr. Bennett notes the difference between even change in visibility when the effect is simply one of glare, as in the case of smoke, and the sudden change from moderate visibility to no visibility in case of fog, which diffuses light.

Dr. Lewis F. Richardson presented results on "The Reflectivity of woodland, fields and suburbs, between London and St. Albans," obtained from airplanes. The reflectivity for red light ranged from slightly under 4 per cent for woodland and the reservoir to 6 per cent for brown standing wheat. For green light, the reflectivity ranged from 3½ per cent for tall woodland to 8½ per cent for bare land. The reflectivity of blue light was still less, ranging from about 2 per cent for wood land and green fields to 4 per cent in villas and gardens. The reflectivity of sand, cement slabs, or earth when dry is roughly double what it is when they are wet. The reflectivity of water, so conspicuous at nearly grazing incidence, falls off to nearly 2 per cent incidence according to Fresnel's formulæ; so that of the light reflected from the reservoir about one-half comes from below the air-water interface.

Thora C. Marwick presented observations on "The electric charge on rain," made in New Zealand. Of all the rain measured, 76.5 per cent was positively charged; of thunderstorm rain 94.6 per cent was positively charged; of ordinary rain 79.5 per cent; and of a little drizzling rain, 100 per cent. Sleety rain accompanied by hail had a considerable negative charge.

J. E. Clark, and I. D. Margary presented a general article on Floral isophenes and isakairs, for England. Phenological dates for flowering plants in England when averaged over a 35-year period are practically the same as for a 30-year period. The 35-year normals have been used as a basis for determining departures in individual years. Departures were read by comparisons between the average map and the maps for each year for each intersection of half degrees of longitude and latitude. The earliness and lateness of the season is not always related in an obvious manner to the temperature or sunshine of the preceding few months. Conditions in the previous fall may have something to do with the dates.

E. W. Bliss in "A study of rainfall in the West Indies," showed that the March to May pressures in central Siberia and Charleston, S. C., and temperatures for St. Vincent indicate the West Indies rainfall for June to December following, with the correlation coefficient of 0.69. High rainfall follows a weak Azores high. The delay is thought to depend upon the westward movement of ocean waters in the north Atlantic.

Sir Gilbert T. Walker in a note "On the mechanism of tornadoes" suggested that tornadoes are whirls essentially on a horizontal axis the equatorward end of which dips to the earth. This idea was not generally acceptable to those who discussed the paper.

Among the notes, is a discussion of "Winter thunderstorms in the British Isles," in the period from October to March, inclusive. During the past three winters the number of days on which thunderstorms occurred anywhere in the British Isles are 96, 92, 69. The stormiest regions are the west and north of Ireland, the northwest of Scotland and the English lake district.

Reviews of the book by August Schmauss, and Albert Wigand, "Die Atmosphäre als Kolloid," and of W. P. von Poletika's "Klima and Landwirtschaft Russlands," are included in this issue.—*C. F. B.*

Climatology of the Virginias [1] (*by E. Ray Casto, Emory and Henry College*) [*author's abstract*].—The Virginias lie in one of the favored climatic regions of the world. Each of the climatic factors is markedly influenced by the widely diversified topography of the region. And the divergent winds tend to equalize other climatic elements and to give less variable climate.

[1] Submitted as a thesis as part requirements of the degree of Ph. D. at Clark University Worcester, Mass., in 1926.